Chapter 19
Liquid-Phase Carbon Adsorption

19-1. General

The process of liquid-phase carbon adsorption and its applications are described in the chapter's first section. The second portion of the chapter is a hazard analysis with controls and control points listed.

19-2. Technology Description

a. Process.

Adsorption by activated carbon has a long history of use in treating municipal, industrial, and hazardous waste streams. In liquid-phase carbon adsorption, contaminated water is pumped through activated carbon contained in a vessel or series of vessels and the dissolved contaminants are adsorbed. When the contaminants saturate the carbon, it is regenerated in place, removed and regenerated off site, or removed and sent off-site for disposal. Often, carbon used for explosives or metals-contaminated water cannot be regenerated and will require off-site disposal. See Figure 19-1.

Each chemical has a different affinity for the activated carbon, depending on its chemical and physical properties, such as its configuration. Therefore, each chemical is adsorbed to a different degree (and mass ratio). Adsorption isotherms for many organic chemicals are available from manufacturers of the activated carbon. These isotherms predict what weight of the chemical will be adsorbed at standard equilibrium conditions at specified temperatures per unit weight of carbon.

The treatment is not destructive, but binds the contaminants to the carbon and concentrates them in the carbon. The used carbon can then be readily processed or transported for post-treatment destruction of the target chemicals.

b. Application.

The effectiveness of activated carbon is a function of the individual chemicals being treated, their combination with other chemicals, residence time, temperature, and other factors. Activated carbon is most effective in adsorbing non-polar molecules, such as aromatic hydrocarbons. Chlorinated volatile organic compounds are generally not adsorbed as well as their non-chlorinated hydrocarbon analogues. The method is particularly effective on multi-ring compounds, such as aromatic hydrocarbons (PAH) and chlorinated biphenyls (PCB), which are strongly adsorbed.

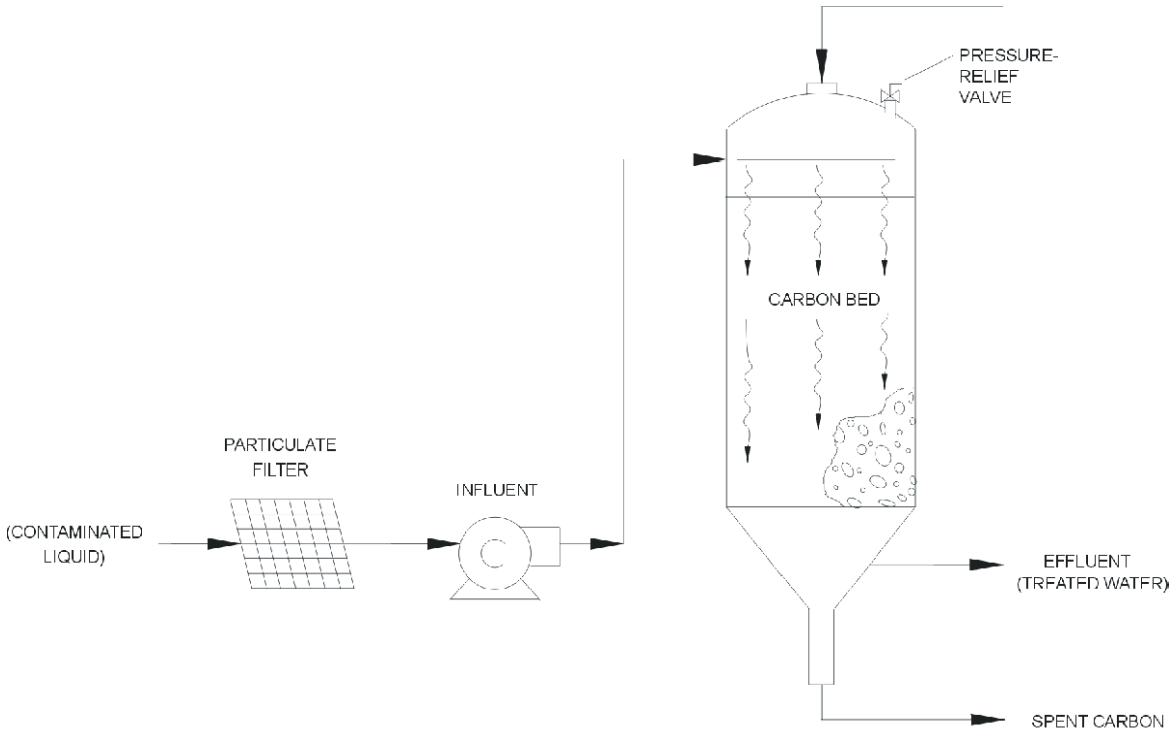

FIGURE 19-1. LIQUID-PHASE CARBON ADSORPTION

The treatment is less effective for short, volatile organic compounds (VOC) and chlorinated VOCs, such as alkanes and alkenes, which are not strongly adsorbed. Oxygenated solvents and very small organic molecules (e.g., acetone, methyl ethyl ketone (MEK) and vinyl chloride) may not be adsorbed to any useful degree. For metals, the adsorption ability of the carbon is limited.

This technology is best suited to streams with low concentrations of the organics. Streams with relatively high organic loadings will require more carbon per unit of flow than more dilute streams.

19-3. Hazard Analysis

Principal unique hazards associated with liquid-phase carbon adsorption, methods for control, and control points are described below.

a. Physical Hazards.

(1) *Confined Spaces.*
Description. Entering the carbon bed tanks for activities such as inspection, repair, and maintenance may constitute a confined-space entry. Hazards associated with entry into confined space include asphyxiation from the lack of oxygen, exposure to toxic contaminants and poisonous gases, inhalation of fine

carbon particles, which may carry microbes, and engulfment/entrapment by the carbon.

Control. Controls for confined spaces include:

- Design the carbon bed tanks to maximize ease of operation and maintenance and minimize the frequency, duration, and extent of cleaning and maintenance that will be required.
- Implement a confined-space entry program. Develop a pre-entry confined space permit (see 29 CFR 1910.146) to include atmosphere testing inside the tanks both prior to entry and throughout the work.
- Ventilate the tank prior to and during the confined space entry. Activated carbon in the confined vessels can exhibit a measurable oxygen demand, which can create the oxygen-deficient atmosphere.
- Complete the carbon bed tank manufacturer's shutdown procedures and lock-out/tag-out of associated pumping or electrically energized systems prior to entry. Eliminate possible buildup of static electricity.
- Use air-supplied respirators to control inhalation exposures to toxic chemicals and prevent any potential for asphyxiation in situations where constant mechanical ventilation does not adequately prevent the buildup of a toxic or inert gas.

CONTROL POINT: Operations, Maintenance

(2) *Fire/Explosion (Spent Carbon).*
Description. Spent carbon used to remove explosive or reactive contaminants may pose a potential explosion and fire hazard during carbon regeneration or removal from the tank.

Control. Controls for spent carbon include:

- Do not regenerate carbon used to remove potentially explosive contaminants (e.g., explosives, highly volatile organic chemicals). Heat used to regenerate the carbon may ignite or explode the adsorbed material.
- Perform a Process Hazard Analysis (PHA) prior to startup and correct all deficiencies found.
- Thoroughly train operators in emergency procedures in the event of a catastrophic failure, in life saving first aid procedures including halting chemical reactions, extracting, decontaminating, and stabilizing victims, and in emergency system isolation and shutdown procedures.
- Locate emergency eyewashes and showers at critical points throughout the system. (See American National Standards Institute ANSI Z358.1 – 1998.)

CONTROL POINT: Design, Operations, Maintenance

(3) *Fire/Explosion (Over-Pressurization).*
Description. Carbon beds are normally operated under pressure. Over-pressurization may result in explosion or fire from overheating of the pump motor.

Control. Controls for over-pressurization include:

- Use experienced operators and supervisors who are trained in operating carbon bed and waste stream transfer systems.
- Perform a Process Hazard Analysis (PHA) prior to startup and correct all deficiencies found.
- Hydro test systems in accordance with UFGS 11225A, "Downflow Liquid Activated Carbon Adsorption Units," before the system is put into operation.
- Add warnings for contents under pressure.
- Train operators in emergency procedures in the event of catastrophic failure, in life saving first aid procedures including halting chemical reactions, extracting, decontaminating, and stabilizing victims, and in emergency system isolation and shutdown procedures.
- Locate emergency eyewashes and showers at critical points throughout the system. (See ANSI Z358.1 – 1998.)

CONTROL POINT: Design, Construction

(4) *Electricity*.
Description. Electrical systems in wet or damp areas can cause electrical shock, burns or death.

Control. Controls for electrical shock include:

- Verify that drawings indicate hazardous area classifications as defined in NFPA 70, Chapter 5, sections 500.1 through 500.10.
- Use controls, wiring, and equipment that meet the requirements of EM 385-1-1, Section 11, NFPA 70, and UFGS 16415A, "Electrical Work, Interior."
- Use grounded equipment or equipment with ground fault circuit interrupter (GFCI) protection if required by EM 385-1-1, Section 11, or NFPA 70.
- Perform all electrical work according to codes and under the supervision of a state licensed master electrician.
- Never allow the use of ungrounded, temporary wiring during maintenance work or wiring that is not approved for contact with water, or use in wet or damp conditions.

CONTROL POINT: Design, Construction, Operations, Maintenance

(5) *Life Safety (Treatment Buildings).*
Description. Treatment buildings may present life safety hazards such as inadequate egress, fire suppression systems, or emergency lighting systems.

Control. Controls for treatment buildings include:

- Meet the following construction requirements for permanent and semi-permanent treatment buildings: ANSI 58.1, "Minimum Design Loads for Buildings and Other Structures," the "National Fire Code," the "National Standard Plumbing Code," "Life Safety Code," and the "Uniform Building Code."

- Make sure structures comply with either the Air Force Manuals on Air Force bases, the USACE Technical Manuals on Army installations, or local building codes on Superfund, Base Realignment and Closure (BRAC), or Formerly Used Defense Sites (FUDS) projects.

CONTROL POINT: Design, Operations

(6) *Fire*.
Description. Some of the chemicals in the waste stream may present a fire hazard during treatment; for example, hydrogen sulfide may cause carbon bed fires owing to the high heat of adsorption or peroxides may auto-ignite.

Control. A control for fire includes:

- Use experienced operators and supervisors. Train them in both the flammability/reactivity characteristics of the waste feed liquid and possible reaction outcomes when in contact with carbon, the exposure hazards of the waste feed, and the design operating parameters of the carbon beds.
- Audit and apply proper quality assurance/quality control (QA/QC) to assure the pretreatment and carbon bed systems are operated as designed.
- Operate the system and waste feed system within design parameters.
- Do not allow the waste stream flow to exceed the capacity of the system.
- Monitor and control temperatures of carbon beds continuously.
- Select an alternate technology during design if the known or anticipated contaminants pose an unmanageable threat of fire.
- Thoroughly train the operators in emergency procedures in the event of a catastrophic failure, in life saving first aid procedures including halting chemical reactions, extracting, decontaminating and stabilizing victims, and in emergency system isolation and shutdown procedures.
- Locate emergency eyewashes and showers at critical points throughout the system. (See ANSI Z358.1 – 1998.)

CONTROL POINT: Design

(7) *Emergency Wash Equipment*.
Description. Emergency shower/eyewash equipment required per 29 CFR 1910.151 is not always provided with adequate floor drains, thereby creating potential electrical hazards or walking surface hazards during required testing and use.

Control. A control for emergency wash equipment includes:

- See American National Standards Institute ANSI Z 358.1 – 1998: "Emergency Eyewash and Shower Equipment" for design requirements.
- Equip showers/eyewash equipment with accompanying functional drains to isolate and collect the shower/eyewash water from unprotected electrical equipment and walking surfaces that, when wet, create slipping hazards.

CONTROL POINT: Design

(8) *Design Field Activities.*
Description. Design field activities associated with subsequent construction may include surveying, biological surveys, soil gas surveys, geophysical surveys, trenching, drilling, stockpiling, contaminated groundwater sampling, and other activities. Each of these field activities may expose the survey personnel to physical, chemical, radiological, and biological hazards.

Control. Controls for hazards resulting from design field activities include:
- Prepare an activity hazard analysis for design field survey activities. EM 385-1-1, Section 1, provides guidance on developing an activity hazard analysis.
- Train workers in hazards identified.

CONTROL POINT: Design

b. Chemical Hazards.

(1) *Waste Chemical Exposure (Tank/Pipe Corrosion).*
Description. Workers may be exposed to waste chemicals from system leaks when activated carbon corrodes tanks and piping systems that are made from carbon steel or other corrodible material incompatible with the waste stream to be treated.

Control. Controls for chemical exposure include:
- Do not use carbon steel to contain activated carbon.
- Use stainless steel, thermoplastic, or other chemically inert tank materials.
- Consult EM 1110-1-4008, "Liquid Process Piping," and UFGS 15200A, "Liquid Process Piping," for appropriate materials for pumping various fluids.
- Paint, coat, or line tank interiors to prevent contact between activated carbon and corrodible substructures.
- Install spill or leak detection instruments, including alarms if necessary.
- Include drip pans or receivers to monitor leaks and sources of potential exposures where leaks may occur.
- Locate, install, and maintain emergency eyewash and showers at critical points throughout the system. (See ANSI Z 358.1 – 1998.)
- Train workers in potential chemical exposure hazards and controls (see 29 CFR 1910.1200).

CONTROL POINT: Design, Construction, Maintenance

(2) *Plugged Waste Lines.*
Description. Sludge from the waste may plug transfer lines or piping at slow flow velocities. Plugged waste lines may cause tanks to increase pressure, possibly causing a leak that exposes workers to waste material.

Control. Controls for plugged waste lines include:

- Include adequate flow controls and pipe velocities in design.
- Use filters to remove solids prior to carbon bed treatment.
- Implement a routine system operation inspection.

CONTROL POINT: Design, Operations, Maintenance

(3) *Carbon Holding Tanks/Drums*.
Description. Carbon holding tanks or drums may leak or spill over into the surrounding areas, resulting in worker exposure during operations or loading and unloading of carbon.

Control. Controls for carbon holding tanks/drums include:

- Equip holding tanks or drums with adequate spill containment.
- Install spill or leak monitors and alarms if necessary.
- Train workers in proper handling techniques and the hazards associated with handling and exposure to new or spent carbon.

CONTROL POINT: Design, Operations, Maintenance

(4) *Water Transfer Equipment*.
Description. Water transfer system equipment (pumps, piping, pipe fittings, valves, and instruments) in contact with contaminated liquids can corrode or dissolve to a point of failure and cause facility damage or worker exposure to waste chemicals.

Control. Controls for water transfer equipment include:

- Use water transfer system equipment fabricated from materials that are chemically resistant to the contaminants.
- Consult EM 1110-1-4008, "Liquid Process Piping," and UFGS 15200A, "Liquid Process Piping," for appropriate pumping materials.
- Include containment drip pans or receivers where leaks may occur.
- Install spill or leak detection instruments.
- Implement a routine system operation inspection.

CONTROL POINT: Design, Construction, Maintenance

(5) *Plugged Carbon Bed (Biological Growth).*
Description. Under certain operating conditions, biological growth can occur inside carbon beds. This growth may foul or plug the carbon bed flow pores, which may cause an increase in system pressure. The pressure may cause leaks that expose workers to chemicals.

Control. Controls for biological growth include:

- Train operators on system parameters in relation to the waste stream being treated.

- Develop and implement QA/QC procedures to optimize and maintain optimal performance of the carbon beds.
- Periodically feed biocides into the system.
- Backwash with biocides or bleaches to minimize or remove the biological growth.
- Replace, regenerate, or dispose of the carbon.

CONTROL POINT: Maintenance

c. Radiological Hazards.

(1) *Radioactive Material*.
Description. In some geological settings, dissolved naturally occurring radioactive materials (NORM) or radioactive contaminants may be drawn up with the groundwater. Depending on the chemical form, the radioactive component may be trapped by the activated carbon and concentrated in the filter to a point where a radiation hazard may develop.

Control. A control for radioactive material includes:
- Consult a qualified health physicist if elevated levels of NORM or radioactive contaminants are in the groundwater.

CONTROL POINT: Maintenance

(2) *Radioactive Devices.*
Description. Fire and smoke detection devices, fluid level devices, and other process monitors and switches may contain radioactive devices potentially exposing workers through lack of identification or mishandling.

Control. Controls for inadvertent handling or exposure to radioactive devices include:
- Workers should be prevented from and warned against tampering with the devices.
- The location of the devices should be recorded so as to safely retrieve and dispose of them in case of a system failure and equipment replacement.

CONTROL POINT: Design, Operations and Maintenance

d. Biological Hazards.

Opportunistic Insects and Animals.
Description. For all sites but especially in cooler climates, opportunistic insects or animals can nest in and around warm process equipment. Vermin, insect, and arthropod control measures should be considered in any design.

Control. Control of opportunistic insect and animals include:

- Electrical cabinets and other infrequently opened enclosures should be opened carefully and checked for black widow and brown recluse spiders, and evidence of rodents. As rodents can cause damage to electrical cables, all wiring should be inspected regularly.
- Ensure all storage is off the ground, palleted, and kept dry. Damp areas attract scorpions, rodents, and the snakes that eat them.
- Design ceiling corners and other high areas to discourage nesting by swallows, pigeons, and other birds. Birds are carriers of diseases, especially in their droppings, which can foul cranes and process equipment.

CONTROL POINT: Design, Operations and Maintenance